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SUBJECT **The Subsurface Water Resources of Iraq**

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The Subsurface Water Resources of Iraq; A. H. Noble; October 1926; 30 pp.

Outline is as follows. /

1. Stratigraphy of Iraq

Cretaceous limestone
Cretaceous shale series
Eocene
Oligocene
Lower Miocene - the Euphrates or Asmari limestone
Lower Fars
Upper Fars
Bakhtiari formation

2. Geological Structure

3. Subsurface Water Conditions in Iraq

Western desert
Alluvial plain of the Euphrates and Tigris
Region between the western frontier of Iraq and Jabal Hamrin north of the Diyala River
Region west of the Tigris and north of Hatra
Region between the Tigris and the Greater Zab
Region between Jabal Hamrin and the Iraq-Persia frontier

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4. Springs

West of the Euphrates

The Alluvial Plain

The region between the Euphrates and the Tigris

Region between the Tigris and the Greater Zab

Region between Jabal Hamrin and the Iraq-Persia frontier

5. Quality of Water

6. Wells and Karez

end

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**UNDERGROUND SPACE WATER RESOURCES
OF IRAQ**

BY

A. H. NOBLE

E1-13
PN27
mar. 13/49

The Stratigraphy of Iraq.

Iraq, as a whole, has a basin shaped structure, the oldest rocks outcropping around the border and dipping under successively younger formations towards the centre of the country. The oldest known rocks are of Cretaceous age and overlying them are thick Tertiary formations. The Mesozoic and older Tertiary crop out on each side of the basin of Mesopotamia, on the west forming a gradually rising limestone country and on the east the mountains of Kurdistan and Persia. The following is the sequence of formations:-

Tertiary	<u>Quaternary</u>	(Recent - Alluvium and gravel of the present drainage system. (Pleistocene- Gravel and clay.
	(<u>Pliocene</u>	- Bakhtiari Formation - gravel, conglomerate, silt and clay.
	(<u>Miocene</u>	- Upper Fars Formation - alternations of sandstone, silt and clay.
	((Lower Fars Formation- gypsum, anhydrite, clay, limestone and probably salt.
	(<u>Lower Miocene</u>	- (Euphrates Lime- massive porous white limestone.
	((stone (Asmari)
	(<u>Oligocene</u>	-(present locally) - Limestone.
	(
	(<u>Eocene</u>	- Limestone and locally other rocks.
		(Shale series - shale and sandstone and conglomerate locally.
	<u>Mesozoic.Cretaceous</u>	(Mountain Limestone - massive limestone.

The water bearing and water yielding properties of the constituent rocks of these formations will now be considered.

Cretaceous Limestone.

This massive limestone of Cretaceous age is conveniently termed the Mountain Limestone. Where it has been examined it is highly folded and although the porosity of the limestone is generally low, it is so highly fractured and jointed that it would certainly hold and yield large quantities of water. The abundance of large springs,

which issue where the water-table is exposed, is clear evidence that it may be an important aquifer, and this is true, notwithstanding the probability that the total volume of fracture space is less than 10%. The eastern parts of the Arbil and Sulaimani Liwas are largely formed of this limestone, but it does not appear to crop out in the western desert within the frontier of Iraq.

Cretaceous Shale Series.

Overlying the Mountain Limestone is a thick formation chiefly composed of dark coloured shales of Upper Cretaceous age; in the Sulaimani district sandstone and conglomerate appear in the middle part of the formation. In general it is an impervious formation and the bulk of the rainfall flows off it. There are no known aquifers in it, except perhaps in the Sulaimani district. Springs issue from its contact with the under and overlying beds. The same formation has been seen in Jabal Sinjar and it doubtless underlies most of the basin of Mesopotamia. It has not been seen in the western desert and it is probable that the shales are replaced by limestone westward; the significance of this is discussed in Chapter 4.

Eocene.

In the Sulaimani district the Eocene is represented by a thick limestone, highly fossiliferous and with a moderate porosity in addition to an induced porosity due to fracturing. Northward the Eocene is represented by a thinner limestone and shale formation. West of the Euphrates it forms a wide outcrop of white limestone with many chert bands and some sandy and marly layers. Springs are fairly common along its outcrop in Southern Kurdistan. It is capable of absorbing water and may be a minor aquifer.

Oligocene.

Beds of Oligocene age are poorly and doubtfully represented in Iraq, and in places completely wanting. Only in Qarah Chaugh Dagh has it been definitely determined. Where present the Oligocene is a limestone formation and for the purpose of this

Lower Miocene - The Euphrates or Asmari Limestone.

Limestone of Lower Miocene age has been given the name "Asmari" in south-western Persia. On account of its wide outcrop on the Euphrates from Hit to the Syrian border, the name Euphrates Limestone has been adopted for western Iraq. Its outcrop encircles Iraq and it is exposed in the core of the Qarah Chaugh Dag, Jabal Makhul and Jabal Hamrin and in several hills near Mosul. It is usually of yellowish limestone of low porosity, though it averages higher in pore space than the older limestones, but locally it has connecting pores and cavities up to several inches across. It has always a certain water yielding quality, due partly to jointing. That it is an important aquifer is proved by the large springs which issue from it, notably those of the zone from Kubeisah to Shithathah. It is overlain by the Lower Fars, which contains many thick beds of gypsum, anhydrite, salt and clay and thus forms an impermeable barrier to upward movement of water.

Lower Fars.

The Lower Fars is a wide spread formation composed largely of gypsum or anhydrite, interstratified with red and green clay, marl, and limestone, the limestone being more common in the lower part. Salt, though not seen on outcrop, is probably present under cover. In Jabal Hamrin and eastward, the Lower Fars forms prominent hills, predominantly white in colour because of the dominant gypsum; the ridges east of Kirkuk, Tauq, and Kifri show its typical mode of occurrence. It underlies the basin of Mesopotamia, attaining its maximum thickness about 2,000 feet - in the zone from Tal Afar, Qaiyarah, between Jabal Hamrin and Qarah Chaugh Dag, Kifri and Naft Khanah. It thins out on each flank and at the same time becomes less gypseous. Eastward the Lower Fars basin of deposition did not extend far east of the Qarah Dag (south-east of Sulaymaniyah) and Sefin Dag (northeast of Erbil). Westward also it probably did not extend

far beyond its present outcrop. The Lower Fars is in general an impermeable formation, although some of the thick limestones are cellular and porous and could be good aquifers. Small springs are common along its contact with the Upper Fars and in a few places streams of considerable size issue from caverns in gypsum, as for example on the northeast flank of the Qaiyarah anticline and in the Wadi Tharthar near Hatra. Whether this water is rising from the Euphrates limestone by means of fissures, or is indigenous to the lower Fars, is an undecided point, but the writer inclines to the belief that some, at least, originates in the Euphrates Limestone. The Lower Fars is an important formation because it seals off the water in the lower beds and also prevents the downward movement of that in the overlying formation.

Upper Fars.

The Upper Fars is composed, essentially, of sand and silty clay, the latter containing a large percentage of carbonate of calcium so that they have been called marls by some writers. It is a widespread formation, thin in the Euphrates region, but thickening to the west and northeast to a maximum of nearly 4,000 feet. The lower part contains a large proportion of red silty clay, with sandstone as a lesser constituent. The upper part contains at least 50% of sandstone. A characteristic is the regular alternation of clay or silt and sandstone and the extraordinary persistence of individual beds over great distances; this is a most important factor in water supply problems. The sandstones are of rather uniform constitution and as they have a very considerable porosity, they seem to have the properties of good aquifers. A few small springs occur in this formation and in many places water may be obtained in shallow wells. The Upper Fars must be considered as an important water bearing formation.

Antiar Formation.

Overlying the Upper Fars, and, in many places, indistinguishable from it, is a similar formation, the lower part of which consists of clay, silt and sandstone and the upper part is characterized by numerous

and thick gravel or conglomerate beds. Westward from the mountains it attains a thickness of more than 10,000 feet and maintains a great thickness as far as the Kirkuk-Tauq-kifri line, westward of which it thins rapidly. It dies out along the line of the Tigris, and, if ever present over much territory west of this stream, it surely had no great thickness. In the lower part, separated by clays and silts are many thick sandstones which would be good aquifers. The gravels of the upper part are excellent aquifers and supply considerable quantities of water by means of Karez. There is some slight element of doubt as to the extent to which the gravels have been cemented into conglomerates, because, if cemented, the pore space is diminished and they become poor aquifers. Generally, however, the voids in the gravel are not nearly filled with cementing substance. It may be confidently anticipated that where such gravels are covered by an impervious bed, and can be reached at a reasonable depth, they will yield water in large quantities. Similar gravel is known to yield from a hole one foot in diameter more than 1,000 gallons minute.

Summarizing the water bearing properties of the formations, aquifers may be found:-

Bakhtiari Formation - Gravel in the Upper part, thick sandstones in the lower part and more or less silty clays throughout.

Upper Fars Formation- The upper part has many thick, silty sandstones, suitable as aquifers. The lower part may also contain some good aquifers.

Euphrates Limestone - known to be a good aquifer, but lies at great depth in the basins and generally has mineralised water.

The Older Limestones- are aquifers to some extent, but do not enter into practical considerations for the country east of the Tigris, because in the more low lying agricultural portion they lie at too great depths.

CHAPTER 3 - GEOLOGICAL STRUCTURE.

The topography of Iraq is controlled very closely by geological formations and structures. The mountains of South Kurdistan

and of the Iraq-Persia frontier south of the Diyala River are formed of highly folded limestone of Lower Miocene to Cretaceous age. Westward is a zone of thick Upper Fars and Bakhtiari with a general dip to the northeast; in this zone are a number of faulted structures in which Lower Fars is brought to the surface. The more regular hills of the Mousl country, Qarah ChaughDagh, Jabal Makhul and Jabal Hamrin (northern part) are simple anticlines, in which Lower Fars and older rocks in the cores have been exposed along the crests and flanks by erosion. The plain of Mesopotamia is filled with recent alluvium, which probably conceals horizontal or gently folded Upper Fars, and in the eastern portion, Bakhtiari beds. The western desert is formed of north-east dipping limestones, the youngest, the Euphrates Limestone, cropping out along the Euphrates River, and the older successively westward. Briefly the geological history is as follows:-

Marine conditions of deposition prevailed throughout early Cretaceous times, giving rise to the formation of a great thickness of limestone. The Upper Cretaceous period throughout most of Iraq and southwest Persia was marked by a shallowing of the sea, and even by estuarine and local land conditions, causing the deposition of a great thickness of clay. The Eocene period was again, so far as is known, marine, and limestone formation predominated, though there may have been times of local and temporary emergence. The Oligocene period included an epoch of regional earth movement and erosion, and limestones of this age have been definitely identified at only one place in Iraq. During the early part of the Miocene period the sea became more and more restricted as the region slowly rose until only an inland sea was left over what is now Iraq and southwest Persia. At first limestone was laid down but it was succeeded by gypsum, anhydrite, salt, clay and limestone, forming what is known as the Lower Fars. In the latter part of the Miocene time the region rose above sea level, either by uplift or by filling of the shallow sea with sands and silts presumably the former, to judge by the lack of marine fossils. The Upper Fars and Bakhtiari seem to have been laid down in vast compound alluvial fans, by streams flowing from the east. Toward the end of the Bakhtiari period great earth movements set in and the rapid uplift of the land to the east caused the streams to bring down increasing amounts of gravel, which was spread over the eastern part of Iraq. Much of eastern Iraq, however, appears to have been subsiding at this time, for the basal Upper Fars which had been deposited near, if not above, sea level sank to a position 10,000 feet or more below sea level, while the basin thus formed was being kept more than filled with silt, sand and gravel.

The great earth movements which have deformed the formations and determined the present structure came mainly after the deposition of the Bakhtiari gravels. The thrust came from

the northeast and caused the strata to be folded along north-west-southeast lines. The rigid limestones were highly folded and elevated into great anticlinoria (assemblages of echeloned anticlines); the less rigid overlying beds were faulted in some places, with the result that westward of the mountains is a zone of faulted structures. In the northern part of Iraq the folding seems to have been less intense, with the result that simple unfaulted anticlines were formed. Westward of the highly folded or faulted region is a region of almost undisturbed strata, with a very gentle regional dip to the northeast. A general section across Iraq from northeast to southwest shows a broad geosyncline, the eastern flank of which is highly disturbed by folds and faults.

South of the Diyala River is a zone of relative uplift in which are a number of strongly folded and faulted anticlines, exposing the Asmari limestone and older beds, whereas the region between the Diyala and the Greater Zab is one of relative depression.

From the hydrologic standpoint the general basin-like structure of Iraq is a favourable factor and the basin has local depressions. For example, the zone of relative depression between the Greater Zab and the Diyala River, closed northward by the general rise of strata and southward by a zone of relative uplift, is on general principles one in which sub-surface water may be expected.

CHAPTER 4

SUBSURFACE WATER CONDITIONS IN IRAQ.

The term subsurface water is used to designate all water which occurs below the surface of the ground, in contradistinction to surface water, with which this report does not deal, except in so far as such surface water has direct bearing on the problem of subsurface water. The water which percolates through the soil or rock gravitates downward to a position approaching equilibrium, the upper surface of the water being called the "water-table". Above the water-table may be a zone of more or less complete saturation into which the water is drawn up by capillarity. It is possible to have two or more water-tables if a body of water is held up locally by impermeable beds above the level of the main water-table. The water-table is not a level surface, but conforms roughly with

the topographic irregularities of the surface; it fluctuates seasonally as the result of the withdrawal or addition of bodies of water, and slopes in the direction of movement of the water.

In Chapter I it has been shown that a portion of the rainfall percolates through the soil and becomes the subsurface water. The amount which percolates depends on the nature of the rocks which lie at and near the surface, but sand, gravel and fractured limestone are the more important of the porous rocks, because they have the largest connecting voids. To provide a large subsurface reservoir, it is essential that there be sufficient rainfall and sufficient area in which porous rocks form the surface - this being known as the "Intake area".

Geological structure is the next consideration; structural basins or synclines, enclosed or open, are the most suitable for the accumulation of water because **it** gravitates into them. The aquifer or aquifers under ideal conditions receive water in the "intake area" in an elevated region, and store it in the basin, whether or not the water is in continuous slow motion toward a lower basin or the sea. When the aquifer is overlain by an impervious layer, the water is prevented from upward movement and artesian conditions are fulfilled. When a well in an artesian area enters the **aquifer**, water will rise to a height above the ground, corresponding to the hydrostatic pressure at that point; that is, the pressure exerted by the water at that point due to the weight of water at higher levels in the same water-table. In some cases the hydrostatic pressure is not sufficient to bring the water to the level of the surface, and such condition has been termed "sub-artesian".

When there is no impervious layer above the **aquifer** the subsurface water forms a water-table, and wells entering it will only fill to the height of the water-table at the point where it is penetrated.

Before studying the subsurface water conditions in detail it is necessary to study the general conditions in Iraq. In Chapter I, the

rainfall was discussed, and it was shown that in north and northeast Iraq there is a rainfall during the winter and spring of 15 to 20 inches, or perhaps, in the mountains 25 inches. In Queensland and South Australia artesian basins are fed by a rainfall of about 25 inches on the mountains of the northeast coast. Therefore, although the rainfall of Iraq is not large, there is still sufficient in the north and northeast to hold out promise of a moderate subsurface supply, if the other essential conditions are present.

The main "Intake area" lies between the Greater Zab and the Diyala River, where Upper Fars and Bakhtiari formations are exposed over a wide area, and both contain about 50% of pervious beds. It seems certain that a considerable proportion of the rainfall percolates through the soil, and is, in a sense, stored in these formations, though it may be in continuous motion toward the rivers and the sea. Eastward of the outcrop of these formations are the older limestones (Lower Miocene to Eocene) the Cretaceous Shale series and the Mountain Limestone of Cretaceous age. The limestones are to a large extent pervious owing to fracturing, and this leads to an important addition to the subsurface water. South of the Diyala the outcrop of the Upper Fars and Bakhtiari is narrow, as the first anticlines, in which the older beds are exposed, are close to the plain.

The western desert is not of importance as an intake area, because the rainfall is small and the bulk of it runs off the limestone surface. The region west of the Tigris and north of Jabal Bakhtul receives a moderate rainfall and there are considerable areas in which Upper Fars is exposed. It is a minor intake area, and will be considered when that part is discussed in detail.

Structurally Iraq is a geo-syncline; the map shows the encircling outcrop of the Lower Miocene limestone (Euphrates or Asmari), which underlies the basin at great depth except where it has been brought near to, or actually to the surface in anticlines. It is

considered by the writer to be an important aquifer because of its obvious voids and because it yields big springs in many places e.g. in the zone from Kubeisah to Shithathah. On the east side of the basin water enters it at an elevation of over 2,000 feet above sea level; could it be reached by the drill in the basins, it is certain that it would yield water under artesian pressure. The prospect of reaching it will be discussed below. Unfortunately it gives highly mineralized water in many places and sulphurous water in most places, so that even if it could be reached it might have no value.

An important question to study is the movement of subsurface water. The surface water all moves toward the Persian Gulf. The axis of the Iraq Geo-syncline plunges gently to the southeast, therefore there must be a general movement of the subsurface water in that direction. One of the problems for investigation is whether there are basins, which are closed or constricted at the southwest end. If so, then there are prospects of getting water from them under artesian conditions.

The Euphrates Limestone and the Eocene limestones are underlain by a thick impervious shale series, but below the latter is more limestone, which is an aquifer and received a large quantity of water in the mountains. What happens to this water? It is a probability that the shale series underlies the plain of Iraq but it has not been observed in the western district, where it may be represented by limestone. In this case the water below it would have access to the upper formations. It is a possibility that the large springs of the Kubeisah - Shithathah zone are due to the liberation of this extra water.

The Lower Fars, which is a relatively, if not a highly impervious formation reaches its maximum thickness in the middle of the basin and becomes thin on each side. Along the line of the Qarah Dagh (Sulaimani Liwa) Koi Sanjak, Agra and Dohuk it is almost non-existent and having only a little gypsum in it, can no longer be considered as an impervious formation. It may be concluded that in

the extreme eastern part of the basin it is not a serious obstacle to the movement of water from the limestones into the Upper Fars and Bakhtiari.

Another problem, and one to which no definite answer can be given, is the effect of the faults of the Kirkuk, Faoq and Kifri structures on the movement of water. These faults are of great magnitude in some places, bringing various horizons of Upper Fars and Bakhtiari into contact with Lower Fars. Whether water is sealed off on the east side of these faults, or whether it moved freely across them, is uncertain. If it were sealed off from movement basinward, large springs might be expected along the faults. This does not occur; on the contrary, seepages of oil occur in this position. The writer is of the opinion that a considerable proportion of water moves from the limestones into the Upper Fars and Bakhtiari, and that the faults do not prevent normal movement westward to the deeper parts of the basin.

It has been found convenient to divide Iraq into a number of districts in order to consider the subsurface water conditions in detail.

(a) The Western Desert.

This includes the territory west of the Euphrates to the frontier with Arabia (Ibn Saud). The writer is familiar with parts of this territory, but vast stretches have not been examined. The immediate vicinity of the Euphrates is watered by canals and there is an irregular fringe of vegetation. Between Ramady and Kerbala is a basin, in which are several lakes, of total area of over 600 square miles. Lake Habbaniyah, at the northern end of this basin, is filled by the flood water of the Euphrates, but by evaporation becomes somewhat saline during the dry season. On the south side it is only separated by a low ridge from Lake Abu Dibs, in which highly saline water is left during the summer. At its south end Abu Dibs is connected by canal with the river, and flood waters enter it via Razazah. Sir W. Willcocks planned to utilize this basin for the storage of flood waters. From Kubaishah to Shithathah

is a zone of artesian springs issuing from the Euphrates limestone or the overlying Lower Fars; they are fully described in Chapter 5. It is worthy of note that they occupy a position approximately southwest of the greatest intake area, and appear to be due to the forcing out of water under hydrostatic pressure, generated in the mountainous region of the Arbil and Sulaimani Liwas. South of Najaf are many small springs, which yield enough for the irrigation of small areas.

The desert is formed of very gently dipping limestone. The rainfall is small, but falls heavily for short periods. Most of it runs off, causing the wadis to fill rapidly and as quickly to become dry again. The most important wadis are the Hauran, which enters the Euphrates between Hit and Anah, the Ghadaf, Ubeidh and Ukheidher, which enter the salt lake basin of Abu Dibs. Further south are no important wadis except the Shabicha, although far to the west are many which seem to disappear before reaching the Euphrates. The desert offers pasture to nomadic tribes, during part of the year, when they depend on the water left in the wadi bottoms, or on water holes which during the dry season become dry or foul. (See photograph No.4).

The old pilgrim road from Najaf to Mecca, along which are ruins of the early Mohammedan period, was provided with wells at intervals of about ten miles. These wells are lined with masonry at the top, and some of them are ten feet square and dug in solid limestone to depths varying from 300 to more than 500 feet. Water was found in only one well, at about 500 feet (See Photograph No.3). The water table about thirty or forty miles south of Najaf is near sea-level, and southwards rises with the rise of the land, standing probably 100 to 200 feet above sea level. In the wadi Shabicha, at an altitude of about 700 feet, are wells in which water stands at about the level of the wadi bottom. This may be due to a local condition, as there is an outcrop of red marl here which may cause a separate water-table. It is interesting to speculate whether the

that these wells formerly supplied the needs of large caravans, whereas to-day, with one exception, they are dry. It is a possibility that they have caved in and that they could be made to yield water if cleaned out.

In the desert it is highly improbable that any valuable water supply could be obtained, because the rainfall is low, and the water-table seems to be, in most places, at a depth of more than 500 feet below the surface, unless the deep dry wells are to be interpreted as being in rock that is water bearing but not *water* yielding. The limestone is poorly porous and highly silicified, and would not yield water freely.

The town of Najaf is very poorly supplied with water; wells are sunk into the Upper Fars on which the town is built, and a small inconstant and probably highly impure supply is obtained. In the plain below are many springs, which are potable although said to be slightly saline during the dry season. The Euphrates limestone could be reached at a depth of about 250 feet. It might be worth while to try one or two borings, but it is certain that the water would not rise to or near the surface and would have to be pumped.

It is probable that the Euphrates limestone will yield a certain quantity of water wherever it is entered by a well and in places a large flow might be obtained. It lies at a depth of less than 500 feet near the river from Kerbela southwards and at lesser depths away from the river toward the outcrop. Occasion may arise at some time to make a test in a favourable spot.

(b) The Alluvial Plain of the Euphrates and Tigris.

The alluvial plain formed by the Euphrates and Tigris is about one hundred miles broad on the average; it extends from the Persian Gulf to the Diyala River. Northwards of the Diyala the alluvial deposits are thin and the more solid formations, mostly Upper Fars, crop out in some places between the two great rivers.

The Tigris is a broad river as far as Kut-el-Amara, south of which it narrows and loses water by distributaries. The Euphrates south of the Hindia Barrage has many channels and canals, and between Basiriya and Basra forms a series of lakes, at times connected and known collectively as Hamar Lake. Many rivers flow from the Persian hills into Iraq between Mendali and the Harun River, carrying a large volume of water during the rainy season, but becoming dry during the summer. These streams, for the most part, do not enter the Tigris above the surface, but discharge into marshes, from which much is lost by evaporation, but part goes into the subsoil and thus into the Tigris. The fall of the lower part of the Tigris is very small; at Bagdad it has an elevation of 120 feet, at Kut-el-Amara 57 feet and at Amara 28 feet, giving a fall of about six inches to the mile. The edge of the alluvial plain between Mendali and Badra stands at about 400 to 500 feet, sloping toward the southwest, thus the streams have a slope of about 20 feet to the mile before they disappear. The alluvium throughout the plain is saturated with water, which is moving slowly toward the Persian Gulf. The alluvium consists of clay, silt, sand and gravel, through part of which water can move freely. Water can be obtained at shallow depth in any part of the plain, but will not flow, as it will stand at a level largely dependent on the river level. From gravel, particularly if underlain and overlain by an impervious bed, a good yield might be obtained by pumping, but it is impossible to detect such places.

Several of the streams which flow from the Persian mountains between Mendali and Badra are strongly saline, whereas others give good water. In general water from the plain will be of good quality, but here and there saline water may be expected.

(c) Region between the Western Frontier of Iraq and Jabal Hamrin north of the Diyala River.

This region is permanently settled only along the banks of the Tigris, although formerly there were large settlements such as the parthian city of Hatra. The desert between the Euphrates and

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Tigris and between the Tigris and the Jabla Hamrin is occupied by nomadic tribes. Between the Euphrates and Tigris the land rises to an altitude of 500 - 600 feet, is remarkably flat and broken only by the Tharthar valley, and the great salt lake depression into which the Tharthar discharges. Water holes are plentiful, and the Wadi Tharthar retains water in deep pools throughout the year. Springs issue from the Lower Fars in the Wadi Tharthar and at Hatra but the water is highly mineralized and unpleasant to drink, although perhaps preferable to the water holes used by the Arabs. The large population of Hatra must have depended partly on the small springs, shallow wells and probably rain water stored in underground reservoirs.

Upper Fars crop out between the Tharthar and the Tigris, and almost horizontal Lower Fars is found far west of the Tharthar. The district west of the Tharthar is characterized by great depressions, which fill up with water after the rains and during the dry season leave widespread but thin deposits of salt. The Tharthar discharges into a great depression which is about fifteen feet below sea level. Between the Tigris and Jabal Hamrin there are no exposures of formations.

Subsurface water conditions are difficult to gauge. Considering first the area west of the Tigris, the Upper Fars contains beds which might be aquifers, but structural conditions are unfavourable and the great amount of selenite, scattered throughout the formation, would almost certainly, make any water it contained unsatisfactory for drinking. It is certain that the Euphrates Limestone could be reached; for example at Hatra, it probably lies at a depth of about 1,000 feet and westward at shallower depths. Although it is an aquifer it is doubtful if it would yield water under pressure in this area. Since there is no great promise of plentiful supplies of good water here, the unpopulated state of the district would make it an unpromising place for a test, although in other circumstances testing would be warranted.

The triangular area contained between the Tigris, Jabal Hamrin and the Diyala river gives no surface evidence of the under-

ground structure and only the data of surrounding country can be used. Jabal Hamrin is steeply folded on its south-west side, in places vertical and even overturned; important faults appear a few miles north and continue south of the Adhim River. It is probable that a deep syncline lies close to the south-west side and that westward the strata flatten quickly and then rise gradually to the west. Southwest of Jabal Makhul the Lower and Upper Fars flatten quickly. Using all available evidence it is computed that the Euphrates Limestone will lie at a depth of about 2,000 - 3,000 feet below sea level in the vicinity of Samarra and will fall to 5,000 feet about half way between the Tigris and the Diyala south of Jabal Hamrin. It is possible that water under considerable pressure might be encountered there because the Euphrates Limestone around Fathah is exposed at elevations of 500 feet or higher, but the great depth at which it lies makes exploration impracticable at present. The Euphrates Limestone is overlain by Lower Fars, thickening eastward, and by Upper Fars; in the latter formation are good aquifers and a certain amount of water can be confidently expected within the first 500 feet. It must be remembered that the axis of the syncline plunges steadily to the southwest, and that there is a constant movement of water in that direction. The quality of the water is problematical; from the Euphrates Limestone similar water to that of the springs west of the Euphrates might be expected and from Upper Fars it may also be highly mineralized. However, it is conceivable that an open underground channel might be encountered which might have water flowing so freely that the readily soluble salts might be washed out. A test of the Upper Fars down to 1,000 feet is recommended in this region.

(c) Region west of the Tigris and north of Hatra.

This region is treated separately because its geological structure is different from that of other areas. The characteristic feature of the topography is long hills of northwest southeast

orientation separated by wide valleys. The rainfall is greater than that of Baghdad but less than that of Kirkuk. The run-off is high, as much of the surface is formed by impermeable Lower Fars, and the wadis become torrents during the rains. There is some cultivation along the Tigris and, west of Mosul, some dry farming. The region is occupied by nomadic tribes, particularly during the winter and spring, as the whole country becomes grass covered. The upper part of the Wadi Tharthar contains water in pools throughout the year and there are many water holes. Springs occur in a few places e.g. Qaiyarah (highly sulphurous) and along the south-west side of Jabal Ibrahim and its continuation; these are all sulphurous but are used on a small scale for irrigation. In general the potable water is obtained from water holes in Upper Fars and in the district west of Mosul from wells in the Lower Fars.

The geological structure is simple, Lower Fars is brought to the surface in a series of anticlines, e.g. Jabal Makhul, Jabal Khanuqah, Qaiyarah and Najmah, and Jabal Ibrahim, and Upper Fars from the intervening synclines. Northwards the general rise of the land coincides with the rise of the formations, so that north of the mouth of the Greater Zab only Lower Fars is exposed and in the cores of several hills west and north-west of Mosul, Asmari Limestone and older rocks are exposed. The Lower Fars has a thickness of about 1,800 feet and the lower part consists largely of limestone, from which the wells of the villages in the plain between Mosul and Tal Afar obtain a sufficient supply of good water. The water-table varies in the plain, some wells finding it near the surface and others at depths from 100 to 200 feet. Jabal Sinjur, through which the western frontier runs, exposes formations down to and including Cretaceous and the main water supply of this district is from springs.

Nowhere in this region are there closed basins, the structures all plunge to the southeast, therefore the general movement of subsurface water is into the great basin lying east of Jabal Sinjur. Small supplies could doubtless, be obtained in the Upper

Fars beds of the synclines on each side of Qaiyarah and in the syncline of Shergat at moderate depth, but no flowing wells can be expected. The lower part of the Lower Fars yields water of good quality, but not under pressure and only sufficient for domestic supply.

(c) The region between the Tigris and the Greater Zab.

This small triangular area requires special attention, because the part of it south and southeast of Mosul is thickly populated. It is watered by the two great rivers, the Khazir river and several minor streams which usually carry water. The country between the Tigris and the hills of Maglub, Bashiqaq and Safra, is mostly under cultivation as it has a rich soil; most of the land is not irrigated. In many villages the domestic supply is obtained from ponds and shallow wells, which become foul in the dry season. The Lower Fars dips gently to the northeast across the Tigris and Upper Fars appears along a northwest-southeast line from two to four miles east of the Tigris. The three prominent hills of Maglub, Bashiqaq and Safra are steep sided domes in which Asmari and older beds are exposed. There is, therefore, a syncline in Upper Fars, the axis of which lies near these hills and plunges to the southeast.

The large spring, which issues at Barimah at the northwest end of Jabal Bashiqaq shows that there is water of good quality in the Asmari limestone. At Mosul this limestone lies at a depth of about 1,000 feet; between Mosul and the three hills it will be found at depths from 1,000 to 3,000 feet. There is a possibility or even a probability that the limestone underlying this district will contain much water as it is fed by the outcrop of the older rocks along the mountain front and in view of its importance from the point of view of agriculture, it seems worth while to make a test. A certain amount of water may be expected in the sandstones of the Upper Fars, but probably only enough for domestic purposes. This is certainly worth considering in view of the unpleasant supply on which many of the villages depend.

(f) The Region between Jabal Hamrin and the Iraq-Persia Frontier.

This region includes two wide plains, the mountains of Qarah Chaugh Dag, the broken country east of Dibega, Kirkuk, Tauq and Kifri and the mountainous country of the Arbil and Sulaimani Liwas. The Greater and Lesser Zab and the Diyala are the main rivers, but there are other streams with perennial water such as Tauq Chai and Aq Su. Rainfall is abundant in the mountains, perhaps as much as 25 inches, moderate - 15 to 20 inches between the mountains and the Kirkuk-Kifri line and somewhat less between there and Jabal Hamrin. As previously stated, wide outcrops of sandstone and gravel allow free percolation. In general the region is sparsely populated, in the mountains are many villages with small areas of cultivation - grain, tobacco and vines. At the edge of the plain are towns and villages with irrigated fields such as Kirkuk, Tauq, Kifri. The plain of Arbil is rather thickly populated, as the soil is fertile, rainfall sufficient and water plentiful. Water for domestic purposes is obtained from the rivers and canals, springs in the mountains and in some places shallow wells.

The geological conditions in this region have already been described in Chapter 3. Briefly, it is an area of relative depression and forms the eastern flank of the great geo-syncline. Section No.1 shows that there are two major basins, the more easterly one is named here the "Basin of Arbil" and the more westerly one the "Basin of the Jubur", using the name of the important tribe. Connected with the former is the minor "Basin of Dibega" and with the latter the "Basin of Kizil Rubat". In view of the fact that the rainfall is considerable throughout this region and that the formation within the basin contain aquifers, it may be concluded that valuable subsurface supplies of water are enclosed in them. The region will now be considered in sections:-

(1) The Basin of the Jubur.

With the exception of the towns at the foot of the hills on the east side of the basin, there is a very small population.

A few villages are found on the east side of Jabla Hamrin, depending on the springs, which issue at the contact of the Lower and Upper Fars, and on water holes. The middle of the plain is waterless.

The longer axis of the basin runs northwest-southeast. Northwestward the basin is closed by the gradual rise of strata; southwestward Asmari Limestone is exposed in the core of Jabal Hamrin a little south of the Tigris; southeastward it is constricted by the Naft Khanah anticline and Jabal Gilabat; northeastward the southwest flank of Qarah Chaugh Dag, the Kirkuk. Taza-Tauq and Kifri faulted structures form the limit of the basin.

The steep dipping north-east flank of Jabal Hamrin flattens at a distance of some three to four miles from the crest. The same applies to the south-west flank of Qarah Chaugh Dag. Recent deposits conceal the solid formations in the basin. The Euphrates or Asmari Limestone, which in Jabal Hamrin and Qarah Chaugh Dag is exposed at altitudes of 500 to 1,000 feet above sea level, sinks rapidly, so that in the middle of the basin in the vicinity of the Lesser Zab, it is at a depth of 5,000 to 6,000 feet below sea level, and this depth increases southeastward, so that between Tauq and Jabal Hamrin, it lies at a depth of about 3,000 feet. It is evident, therefore, that it is impracticable to attempt to reach this formation in any part of the basin, where it might be expected to yield water. The northwest part of the basin is underlain by Upper Fars beds, but south of the Lesser Zab, the Bakhtiari beds are preserved and the gravels probably underlie the recent deposits some fifteen miles southeast of the river.

A considerable quantity of water enters the basin from the northwest, a certain amount from Jabal Hamrin, but the important question is how much crosses the fault zone from the greater intake area of the east. The most favourable part of the basin is south of the Lesser Zab and particularly south of Tazah, Tauq and Tuz Khurmatu. Aquifers may be found in the upper part of the Bakhtiari formation, especially if gravels are developed, or in the sandstones

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of the lower part. A well carried to a depth of 1,500 feet would be a satisfactory test, although there is prospect of getting a good flow at much less depth. In the northern part of the basin, perhaps fifteen miles on each side of the Lesser Zab there is a thickness of 3,500 to 4,000 feet of Upper Fars or Lower Bakhtiari above the Lower Fars and in any part of these formations aquifers may be expected. In the valley between Jabal Hamrin and Jabal Gilabat and also between Jabal Gilabat and Kifri the Upper Bakhtiari yield water from karez showing that the water table is near the surface.

(2) The Basin of Kizil Rubat.

Between Jabal Hamrin and the hills which run from Naft Khanah to Qaraghan, Jubban Dagb and Jabal Gilabat is a plain in which there is much fertile land. Near the Diyala River it is irrigated, but large areas remote from the river are waterless. "Jubur", and to the southeast there seems to be some closure in the Bakhtiari beds due to the rapid rising of the axis of the Naft Khanah anticline. In this small basin the Asmari Limestone lies at great depth, but the gravels of the Bakhtiari should yield water freely. The most favourable part of the basin is on the north side of the Diyala River and wells drilled to 500 feet should give a good supply.

(3) The Basin of Arbil.

This large basin extends from the Greater Zab to the Diyala River. It is broadest at Arbil and becomes narrow at the southeast end. The plain around Arbil is relatively thickly populated and well watered by many streams from the mountains, supplemented by Karez and shallow wells. East of the Avanagh Dagb is another plain with fertile soil but not well watered. The remainder of the land within the basin is occupied by rough broken country, formed by the Bakhtiari gravel and conglomerate, only supporting a small population in the valleys. The rainfall is considerable allowing dry crops to be grown. At the surface, water is scarce in the gravel country, but can be found in the valleys in small springs and water holes.

Springs also occur in the Upper Fars and Bakhtiari on the west flank of the basin.

The Asmari Limestone crops out at an elevation of 2,500 feet in the mountains and plunges below the younger formations so rapidly that at a distance of five miles from its outcrop it lies at a depth of about 10,000 feet. It lies horizontal for many miles and then rises to an elevation of 1,500 to 2,500 feet below sea level at some points in the faulted structures of Kirkuk and Kani Qadir. It is evident, therefore, that the Asmari Limestone where it might contain water, lies at depths beyond the range of exploration. It is in the Bakhtiari formation that there is hope of obtaining subsurface supplies. The water-table in the Arbil plain is high, as wells or karez obtain a good flow at shallow depth. It is certain that wells bored at any place in this plain will yield a plentiful supply. It is doubtful however, if water is required there or if it could not be obtained more cheaply by karez.

The plain east of the Avanagh Dag offers equal possibilities and apparently stands in greater need of water. Therefore, if a test is made in this basin, some place in this plain, preferably about four miles east of the Kirkuk-Altun Kupri road should be chosen.

Throughout this great basin, it seems probable that water can be obtained at comparatively shallow depths, but the actual necessity of commercial interest will dictate whether and where wells will be put down.

(4) The Basin of Liboga.

Between the Qarah Chaugh Dag and Avanah Dag is a fertile valley, about ten miles wide. It is poorly watered and the domestic supply is partly obtained from shallow wells. To the northwest it is closed by the rise of the strata; to the southeast the middle of the basin is occupied by the small, faulted, elongated dome of Sheikh Ismail. A certain amount of water will move into it from the Northwest, and some from the Arbil basin. The middle of the basin is filled with beds of the Urmia formations, formations,

all being covered by alluvium. There is a good prospect of obtaining subsurface supplies from sandstone beds and the best place for a test would be in the middle of the basin west or southwest of Dibega.

(5) The mountainous region of the Arbil & Sulaimani Liwas.

This country has ample rainfall and excellent springs of good water. No discussion of subsurface water possibilities is necessary.

CHAPTER 5

SPRINGS

Subsurface water finds outlet to the surface in two ways naturally by springs, artificially by wells. A spring is a place where water flows, without artificial help, from the soil or rock to the surface of the land or a body of water. There are two main divisions of springs:-

- (a) ARTESIAN - where the water issues under artesian pressure, usually through fissures which connect with an aquifer.
- (b) GRAVITY - where the water issues owing to an outcrop of the water-table. Contact springs, which flow from the contact of permeable and impermeable beds, belong to this class.

Springs occur in many parts of Iraq; they vary much in quantity and quality of water, temperature and mode of occurrence. They are here described under the same general regional divisions as used in Chapter 4. The major springs or those of special interest are described in detail and the minor ones briefly noted.

(a) WEST OF THE EUPHRATES.

Along a line which runs approximately northwest - southeast are a number of springs slightly warmer than the ground temperature and rather mineralized. Although the water is too sulphurous to be palatable, it is used by the inhabitants and is of great value for irrigation - chiefly date palms. The springs of Kubaisah issue from deep circular basins in the Euphrates Limestone. The water is of a blue colour and flows at the rate of about 3,000 galls. a minute. The group of springs at Hit flow about 900 gallons a minute.

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and the large single spring about 50 miles southwest of Hit about 1,800 gallons. The Bitumen seepages of Jabbah, Awasil and Abu Jir are all associated with springs of sulphurous water; each group has a flow of about 600 gallons per minute. Another similar spring occurs at Jemal, but has not been visited by the writer.

At Rahaliyah, there are some ten springs three of which are large, although not as large as those of Shithathah. The flow of the largest is difficult to gauge, even approximately, but is probably not less than 4,000 gallons a minute. The largest group of the whole district is around the small town of Shithathah, where there are three exceptionally large and a number of small. The largest is in the centre of the town and is estimated at 25,000 gallons a minute. Probably the total flow of all the springs at Shithathah is about 40,000 gallons, (See photograph 1). It is reported that there is no appreciable difference in the flow throughout the year. At both Rahaliyah and Shithathah the springs are situated within the outcrop of the Lower Fars, but as it is thin here and the springs vents are deep, it is beyond doubt that the water finds its way from the Euphrates limestone to the surface through fissures. The springs of this group are considered to be true artesian springs.

Between Najaf and Tuqtaqanah are many springs which issue from the Euphrates limestone; some are small while others have a flow of about 500 gallons a minute and are used to irrigate small areas of land. The water which was tested by the writer in January, was found to be pleasant to drink, being only very slightly saline and not sulphurous. It is stated, however, that during the dry season the flow decreases and the water becomes more saline.

(b) THE ALLUVIAL PLAIN.

No springs of any importance occur in this region.

(c) THE REGION BETWEEN THE EUPHRATES AND THE TIGRIS.

Springs issue from the Lower Fars in the Wadi Tharthar, several of them having a flow of 50 gallons a minute. On the northeast flank of Jabal Qaiyarah is one important spring which issues from a cavern

in gypsum; the water is highly sulphurous and absolutely unuseable.

On the southeast side of Jabal Ibrahim and its southeastward continuation are a number of small springs of sulphurous water. Other small springs occur in this region but are of no importance. The mode of occurrence of such springs is difficult to explain; those of the Wadi Tharthar may be due to the seeping out of water from limestone at or near a point where the water table is exposed. The large spring of Qaiyarah may come up from the Euphrates limestone, but this is a matter of speculation. Those of Jabal Ibrahim are certainly connected with the sharp folding and perhaps faulting of the southwest flank of the anticline.

(d) REGION BETWEEN THE TIGRIS AND THE GREATER ZAB.

Hammam Ali. On the right bank of the Tigris and in the river bed are two springs. The former has a temperature of 109 degrees Fahrenheit and is enclosed in a bath house and the latter a temperature of 118 degrees. Both bring up occasional gobs of bitumen. They are situated in the upper 600 feet of the lower Fars and the depth to the Euphrates Limestone is not more than 1,200 feet. That the water is coming up from a deep seated source through fissures is the natural conclusion and the abnormally high temperature, when the natural cooling is taken into account, suggests a source below the Euphrates Limestone.

There is an important spring at Barimah on the northwest end of the Jabal Bashiqa. The water issues from the Asmari (Euphrates) Limestone at the rate of about 1,500 to 1,800 gallons a minute and is remarkable for the slight degree of mineralization. Smaller springs issue at several places along the southwest flank of the same hill and also from Jabals Maglub and Safrah.

(e) REGION BETWEEN JABAL HAMRIN AND THE
IRAQ-PERSIA FRONTIER.

On both flanks of Jabal Hamrin there are many small springs, some of which are perennial and others only noted during the summer by a small patch of vegetation. The water is invariably bitter and slightly sulphurous, but is used by the nomads for their flocks.

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Near Nukhailah Khan is a small spring with a high concentration of salt; the temperature is 74 degrees Fahr. In several places small but important springs of good water issue from the Upper Fars or Bakhtiari and, some of them, at least, are due to a slight irregularity in dip of the strata. On the southwest side of Qarah Chaugh Dagh near Makhmur is an important spring which yields about 1,500 gallons a minute of slightly salt and perceptibly warm water.

In Avanagh Dagh and the hills which run from Kifri to Kani Qadir and Sheikh Khalil there are a number of small springs of potable water and in several cases small villages depend on them. A typical example is shown in photograph No.2.

An important group of springs occurs near the police post at Makatu north west of Mendali; the water is of good quality and flows at the rate of about 1,500 to 2,000 gallons a minute. They issue from Bakhtiari beds and probably are due to the outcropping of the water-table.

The mountainous region of the Arbil and Sulaimani Liwas abound in large springs, the most important of which issue from the Cretaceous Limestone. The water is crystal clear and sweet. Examples of such springs are those of the Derbend Gorge near Rania and in the valley some 4-5 miles north of the town of Sulaimani. A flow of 2,000 to 5,000 gallons a minute is not uncommon.

CHAPTER 6

QUALITY OF WATER

Up to the present no analyses of spring or well water are available. On the maps there are many notes which differentiate good water from bad, but they do not indicate the reason for the badness. It is presumed that in most cases "bad water" refers to that which is either too saline or sulphurous to be potable. Organically impure water can be rendered potable, but water which contains a high percentage of mineral salts cannot easily be made drinkable. The water of the great rivers is good; during floods it is invariably laden with material in suspension, chiefly clay and sand, but the soluble

matter is not sufficient to make it unpalatable. The following statistics are quoted from "The Irrigation of Mesopotamia" by Sir W. Willcocks 1917.

<u>Parts per 100,000</u>	<u>Euphrates</u>	<u>Tigris</u>	<u>Tigris in Flood</u>
Total soluble salts	44.5	33.9	34.5
Chlorides and common salt	6.4	.7	1.8

The Adhaim after passing through Jabal Hamrin is too salt to drink. Several streams which flow from the Persian hills into Iraq between Mondali and Badra have a high percentage of salt and are undrinkable. On the other hand, all the rivers, with the exception of the Adhaim, which flow into the Tigris north of the Diyala have sweet water. The writer has had the opportunity of trying the quality of the water from a great many rivers, springs wells and water holes in Iraq and although no analyses have been made, a few generalizations are possible. The water from the Cretaceous limestone is of excellent quality. From the Cretaceous Shale Series there is little water but the streams which run through it have good water. At Babachichek about 30 miles from Arbil, a warm, slightly sulphurous, spring issues from this formation.

Water from the Asmari Limestone of the Kurdish Mountain zone is usually sweet, but a large spring of sulphurous water issues from the southeast end of Aji Dag. The springs of Qarah Chaugh Dag, which issue at or near the contact of Asmari limes and Lower Fars are all slightly sulphurous. On the contrary the spring of Barimah (northwest end of Jabal Bashiqah) is only very faintly sulphurous. It seems that where the Asmari is in contact with Lower Fars of normal type, the water is invariably sulphurous to a varying degree; where the Lower Fars is absent or thin and without much gypsum, the water is not appreciably sulphurous. However, it is clear that there is a source of sulphur in some formation older than Lower Fars.

The water from the springs of the Lower Fars is also sulphurous, but near Najaf, where the lower Fars is poorly represented and non-gypseous, the spring water is not sulphurous.

As might be expected all water from springs in the Lower Fars is sulphurous and in some cases highly mineralized e.g. around Ain Nukhailah (Jabal Hamrin), where water with magnesian salts is reported, in addition to a brine spring. Much of this water is undrinkable, but in many places it can be used without serious discomfort.

Upper Fars water is generally better than that from Lower Fars and the nomadic tribes depend almost entirely on water holes in this formation in the districts each side of the Jabal Hamrin. In the Euphrates valley the Upper Fars contains much selenite and therefore the water from it will almost certainly be bitter. Water from the Bakhtiari formation is of good quality, particularly that from the gravels of the upper part. It may have a rather high percentage of calcium carbonate, but is unlikely to contain more than a minute amount of sulphate of calcium.

The subsurface water prospects are limited to the Euphrates Limestone, Upper Fars and Bakhtiari formations. From the first it is probable that any water obtained will be somewhat sulphurous, but useable for irrigation. From the Upper Fars it is liable to be very hard, due to a high content of calcium sulphate. From the Bakhtiari there is every reason to anticipate water of good quality, particularly from the gravels of the upper part.

CHAPTER 7

WELLS AND KAREZ.

There is very little information about the wells of Iraq. For the most part they are shallow and give only a small yield; their water is liable to become much contaminated, as they are usually situated in or very close to the villages. The collection of data concerning the depth of the wells, the water level in them, seasonal fluctuations and quality and quantity of water has now been taken in hand by the Ministry of Communications and Works, Baghdad. The

co-ordination of these data will be a valuable addition to the Hydrology of Iraq.

On the old pilgrim Road from Najaf to Mecca, there are ancient wells at intervals of about 10 miles (see photograph No.3) they have already been described in Chapter 4 (a). In the alluvial plain water can be obtained in wells only a few feet deep in many places. At Mahmudiyah, south of Baghdad, there are a number of wells about 30 feet deep, some of which give good water and others bitter, owing to the presence of gypsum in the vicinity. The villages of the plain between Mosul and Tal Afar depend largely on water from wells in the limestones of the lower part of the Lower Fars. A well at Rihaniyah on the northeast side of Jabal Atshan gives water of good quality from a depth of between 175 and 200 feet. The villages between the Tigris and the Greater Zab obtain water from shallow wells in Upper Fars, but no detailed information was obtained. In the plain east of Avanagh Dag, there are also wells in the Bakhtiari formation.

KAREZ.

This is a name given to a system of water production, which has been practised in Iraq, Persia, Afghanistan etc., for many centuries. Where water is required for the irrigation of land, situated at the foot of hills formed of the gravels of the Bakhtiari formation, a series of wells are dug down to the water table and connected underground by a tunnel. The wells are usually of small diameter - just sufficient to allow a man to descend and the connecting tunnel is also very small. The men who make the karez have acquired great skill in directing their tunnel underground and in maintaining a slope sufficient to bring the water to the surface at the desired place. Section No.3 shows a good example of a karez and is based on one actually constructed near Kirkuk. The slope of the bed of the Karez is 1 in 567 or slightly less than 10 feet to the mile. The wells are spaced about 100 feet apart.

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In Iraq there are a number of successful karez which provide enough water for the irrigation of small choice areas. They can be seen around Kirkuk, in the plain of Arbil, around Kifri and on the sides of Jabal Gilabat.